Variation and changes in state-specific carotid endarterectomy and 30-day mortality rates, United States, 1991-2000

Kazim Sheikh, MD, and **Claudia Bullock, BA,** *Kansas City, Mo*

Objectives: **The objectives of this study were to investigate variations between states and changes in state-specific carotid endarterectomy (CEA) and 30-day mortality rates. Cross-sectional variations and changes over time in such measures may be indicative of improvement in the quality of care.**

Methods: **We performed retrospective analyses of pre-existing administrative data on Medicare beneficiaries aged 65 years and older in the United States. Age-adjusted, state-specific CEA rates and 30-day postoperative mortality rates in 1991, 1995 and 2000 were examined, as well as changes in these rates from 1991 to 1995 and from 1995 to 2000. Stroke mortality in the general population of each state was used as a crude measure of the need for CEA procedure in the state. The Spearman rank correlation analysis was used to study correlations between rates. Oldham's method was used to avoid the effect of regression to the mean.**

Results: **There were wide variations in the state-specific CEA rates, 30-day mortality, and in changes in these rates over time. The states with relatively low procedure rates in 1991 also had low rates in 1995 and 2000, and relatively higher increases in the rates. The states with relatively high 30-day mortality in 1991 or 1995 had lower increases or greater decreases in the rate. CEA rates were not correlated with any measure of surgical mortality, but they were correlated with stroke mortality in the general population.**

Conclusions: **The inter-state variation in CEA rates has not changed much since 1991, but variation in 30-day mortality decreased through 2000. The states with low procedure rates in 1991 did not have sufficient increase to catch up with the high-rate states by 1995, but they were prone to experience a higher increase in the subsequent 5 years. The validity of stroke mortality in a state as a measure of the need for CEA is questionable. Further research using clinical data is needed to better explain variations between states. (J Vasc Surg 2003;38:779-84.)**

Endarterectomy for symptomatic carotid artery stenosis has been practiced for nearly 50 years to prevent ipsilateral ischemic stroke.[1] The appropriateness of this procedure received attention in the mid-1980s in view of its serious complications, stroke and death in particular.[2-4] As a result of better diagnostic and surgical skills, carotid endarterectomy (CEA) was also performed on asymptomatic patients.[5] During this period, many case studies, observational studies, and controlled trials have been conducted to evaluate the benefits of CEA, and many articles, reviews, and editorials have been published in the medical journals. For example, two trials concluded that CEA was beneficial for selected patients with symptomatic and asymptomatic stenosis.[6,7] At the same time, many studies have addressed the serious complications and adverse outcomes of the procedure.[5] These outcomes have usually been measured in terms of in-hospital or 30-day mortality and stroke rates.

From the US Department of Health and Human Services, Centers for Medicare & Medicaid Services.

The views expressed in this article do not represent the views or policies of the Centers for Medicare & Medicaid Services or the United States.

Additional material for this article may be found online at www.mosby.com/jvs.

Reprint requests: Kazim Sheikh, MD, US Department of Health and Human Services, Center for Medicare & Medicaid Services, 601 E. 12th St, Rm 235, Kansas City, MO 64106 (e-mail: ksheikh@cms.hhs.gov).

0741-5214/2003/$30.00 + 0
doi:10.1016/S0741-5214(03)00616-5

Several investigators have reported increasing use of CEA in the mid-1980s and early 1990s, decreasing mortality attributed to the procedure, and sex differences in use and mortality.[8-15] A common goal of some of these observational studies was to investigate the effects on subsequent use of CEA of the results of randomized controlled trials of CEA published between 1991 and 1995. However, none of these studies examined the trends and geographical differences beyond 1996, and most of the studies were limited to select populations and/or brief observation periods. A recent epidemiologic study of Medicare beneficiaries[16] found that from 1991 to 1995, CEA use in the United States increased 70% and 30-day postoperative mortality decreased. Thereafter, there was a small decrease in both rates. Small differences in CEA rates in 3 years between Northeast and Southern regions were the only regional differences found in the study. Variations between individual health care providers or groups of providers, or between geographic areas, with respect to use and adverse outcomes are often useful determinants of the quality of care. The objectives of this study were to use a 100% sample of Medicare inpatient claims data to examine cross-sectional variations in state-specific CEA use rates and 30-day postoperative mortality, and to study changes in these rates over 10 years.

METHODS

The study population comprised all Medicare beneficiaries residing in nonterritorial regions of the United

Table I. State-specific numbers and rates of CEA and 30-day postoperative death among Medicare beneficiaries in 1991, 1995, 2000

Measure	*Year* 1991	1995	2000
No. of CEA procedures			
Median	746	1271	1261
Range	61-4674	98-8240	126-7027
Mean (SD)	1087 (1096)	1901 (1884)	1711 (1588)
No. of 30-day deaths			
Median	15	20	12
Range	0-91	1-113	1-68
Mean (SD)	20.3 (21.3)	28.1 (28.1)	16.3 (15.2)
CEA rate per 1000 beneficiaries			
Median	1.80	3.18	3.05
Range	0.73-2.70	1.10-4.51	1.31-4.64
Mean (SD)	1.84 (0.50)	3.13 (0.70)	3.05 (0.69)
30-day mortality per 100 procedures			
Median	1.87	1.47	0.87
Range	0.0-9.02	0.41-2.17	0.17-2.01
Mean (SD)	1.95 (1.23)	1.44 (0.36)	0.89 (0.40)

CEA, Carotid endarterectomy.

States, who were aged 65 years and older and enrolled in the fee-for-service sector. The International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) procedure code for CEA (38.12) was used to identify hospitalizations for CEA during the period 1991 through 2000 from the Centers for Medicare & Medicaid Services' Medicare Provider Analysis and Review (MedPAR) file. The CEA procedures were excluded if (1) the procedure date was missing or appeared to be in error, (2) hospitalization for a second CEA occurred within 30 days, or (3) coronary artery bypass graft (CABG) surgery was performed during the same hospital stay. (Surgical mortality following CEA is known to be much higher if CABG is performed during the same hospital stay; and a patient has to survive the first CEA to have a second procedure within 30 days. Consequently, 30-day mortality following the second CEA was used in the analyses.) All causes mortality among CEA cases was ascertained from the Medicare mortality file and included in the study if the date of death was within 30 days from the date of the procedure. The CEA and surgical mortality rates were adjusted for age by using the direct standardization method[17] and the 1991 US Medicare beneficiary population as the standard. All CEA rates described here are the number of procedures per 1000 beneficiaries, and the 30-day mortality rates are the number of deaths per 100 procedures. The data on the annual state-specific stroke mortality per 100,000 general population were downloaded from the Web site of the National Center for Health Statistics. This variable was used as an indicator of the risk of stroke and the need for CEA, preventive measure, in the general population. The state code for beneficiaries' residence was used to stratify the data by state.

Complete MedPAR data were available for the years 1991 through 2000, and CEA rates had peaked in 1995.[16] Consequently, three "points" in time—1991, 1995, and 2000—were chosen to study changes over time. The state-specific rates in 1 year were compared with those in the other year and with the percent change in the rate during the period. Twelve state-specific measures of the frequency of CEA procedures and mortality were used in the correlation analyses. These variables were the procedure rates in 1991, 1995, and 2000; 30-day mortality rates for the same 3 years; percent change in the procedure and mortality rates from 1991 to 1995, and from 1995 to 2000; and stroke mortality in the general population in 1991 and in 1999. If two or more of these measures for a state were zero, the state was excluded from the analyses. Accordingly, the District of Columbia and the State of Alaska were excluded.

Because the values of most of the variables were not normally distributed and their scatter plots were not elliptical, the Spearman rank order correlation analysis method in the SAS software (Version 6, SAS Institute Inc, Cary, NC) was used. In order to avoid the possible effect of regression to the mean, Oldham's method[18] of correlation analysis was used to study the relationship between CEA rates or 30-day mortality rates in 1991, 1995, and 2000. According to this method, the averages of 1991 and 1995 state-specific rates (1991 rate + 1995 rate/2) were compared with the differences between these rates (1995 rate–1991 rate).

RESULTS

The ranges, medians, and means of the state-specific numbers and rates of CEA procedures and deaths within 30 days in 1991, 1995, and 2000 are given in Table I. The mean CEA rates increased from 1991 to 1995, and the mean 30-day mortality decreased from 1991 to 1995 and from 1995 to 2000 ($P < .001$). Table II shows a matrix of correlations between 10 variables. Fig 1 shows the frequency distribution of state-specific CEA rates in 1991. These rates were closely correlated with the 1995 rates

Table II. Correlation between state-specific carotid endarterectomy and 30-day mortality rates for Medicare beneficiaries: United States, 1991-2000

	1991		*1995*		*2000*		*Percent change in rate*		
							CEA		*Mortality*
	CEA rate	*Mortality*	*CEA rate*	*Mortality*	*CEA rate*	*Mortality*	*1991-1995*	*1995-2000*	*1991-1995*
1991									
Mortality	−0.030								
	(0.839)								
1995									
CEA rate	0.786	−0.090							
	(.000)	(.540)							
Mortality	−0.096	0.202	−0.142						
	(.513)	(.163)	(.330)						
2000									
CEA rate	0.807	−0.014	0.868	0.028					
	(.000)	(.926)	(.000)	(.847)					
Mortality	0.136	0.054	0.175	−0.111	0.222				
	(.352)	(.712)	(.229)	(.448)	(.126)				
Percent change									
CEA rate									
1991-1995	−0.536	−0.209	0.003	0.008	−0.161	−0.074			
	(.000)	(.149)	(.986)	(.955)	(.271)	(.614)			
1995-2000	−0.005	0.203	−0.249	0.250	0.188	0.083	−0.406		
	(.971)	(.162)	(.084)	(.084)	(.196)	(.569)	(.004)		
Mortality									
1991-1995	0.003	−0.723	−0.060	0.415	0.004	0.077	0.037	0.049	
	(.984)	(.000)	(.684)	(.003)	(.980)	(.599)	(.801)	(.737)	
1995-2000	0.115	−0.049	0.205	−0.626	0.131	0.796	0.015	−0.100	−0.351
	(.432)	(.739)	(.159)	(.000)	(.368)	(.000)	(.917)	(.493)	(.013)

P value for correlation coefficients in parentheses.
CEA, carotid endarterectomy.

(Fig 2, online only). The averages of the state-specific CEA rates in 1991 and in 1995 were also correlated with their differences (r = 0.45, P = .0013), indicating that significant correlation between 1991 and 1995 rates persisted after the effect of regression to the mean was removed. The increase in CEA rates from 1991 to 1995 (between 22% and 175%) occurred in all 49 states. However, the percent increases in these rates were inversely correlated with the 1991 rates (Fig 3, online only).

The range and the mean of the state-specific CEA rates in 2000 were similar to that of the 1995 rates. The CEA rates in 2000 were also closely correlated with the 1991 and 1995 rates (Fig 4, online only). However, 1995 and 2000 rates were not correlated after the effect of regression to the mean was removed (r = 0.01, P = .946). From 1995 to 2000, CEA rates increased (up to 22%) in 22 states. In the remaining 27 states, these rates decreased between 0.3% and 21%. These changes were unrelated to the 1995 rates. Fig 5 shows that the percent changes in CEA rates from 1991 to 1995 were inversely correlated with those from 1995 to 2000. Furthermore, there were wide variations in these percent changes between individual states.

Fig 6 shows the frequency distribution of the state-specific 30-day mortality rates in 1991. The variation in and the mean of 30-day mortality rates were lower in subsequent years (Table I). These state-specific rates in 1991, 1995, and in 2000 were not interrelated. From 1991 to 1995 and from 1995 to 2000, 30-day mortality increased in some states and decreased in others; the percent changes in the two periods were inversely correlated (Fig 7). Table II shows that the percent change in mortality from 1991 to 1995 was inversely correlated with the mortality rates in 1991 (Fig 8, online only) and positively correlated with the mortality rates in 1995. The percent change in mortality from 1995 to 2000 was also inversely correlated with the mortality rates in 1995 (Fig 9, online only) and positively correlated with the mortality rates in 2000.

Stroke mortality in the state-specific general population in 1991 was correlated with CEA rates in 1991 (r = 0.39, P = .0057) and was inversely correlated with percent change in CEA rates from 1991 to 1995 (r = −0.42, P = .0029) in the same state. Stroke mortality in the state-specific general population in 1999 was also correlated with CEA rates in 2000 (r = 0.45, P = .0012) and percent change in CEA rates from 1995 to 2000 (r = 0.53, P = .0001) in the same state.

DISCUSSION

There were wide variations between states with respect to CEA rates and 30-day mortality, and the changes in these rates over time. There was as much as a fourfold difference between state-specific CEA rates in a year. There was even greater (6- to 37-fold) variation between states with respect to 30-day mortality in any given year. A recent

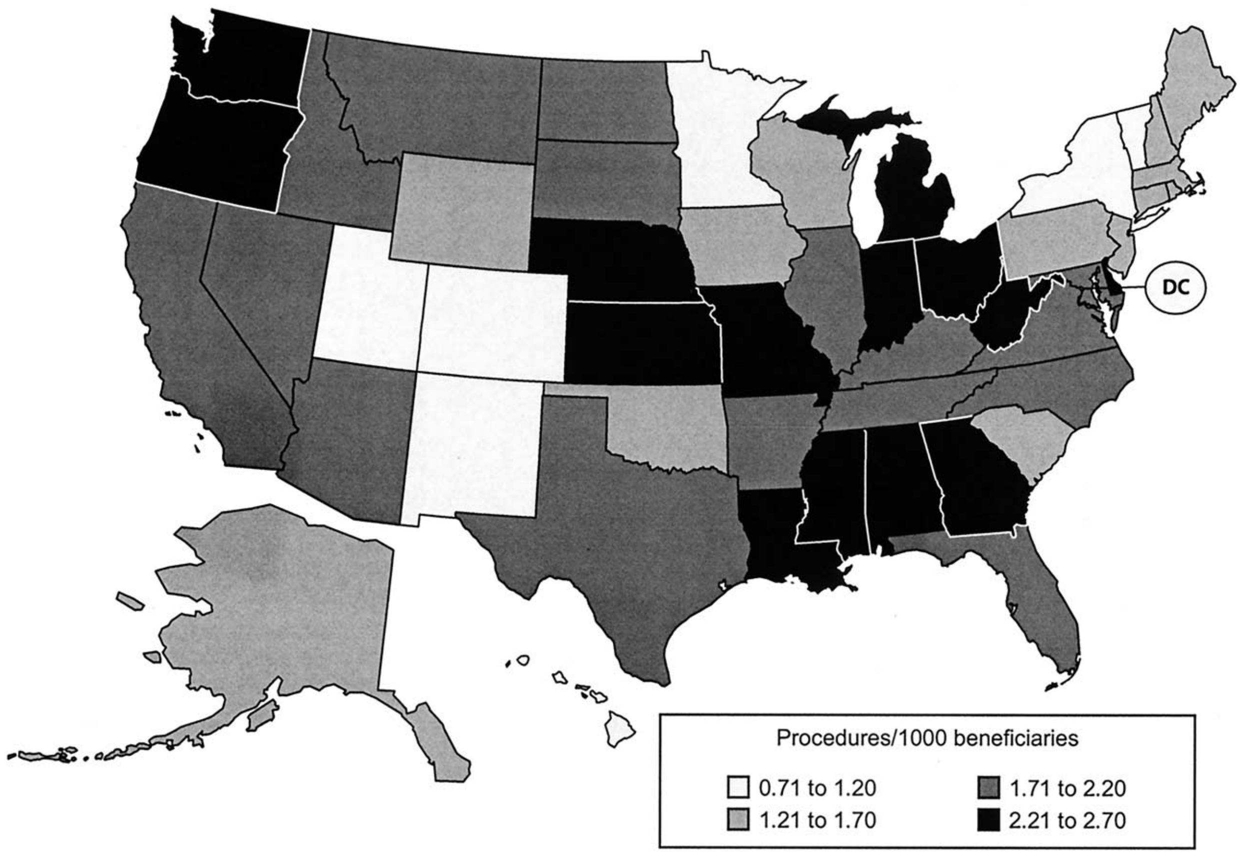

Fig 1. State-specific carotid endarterectomy rate for Medicare beneficiaries, 1991.

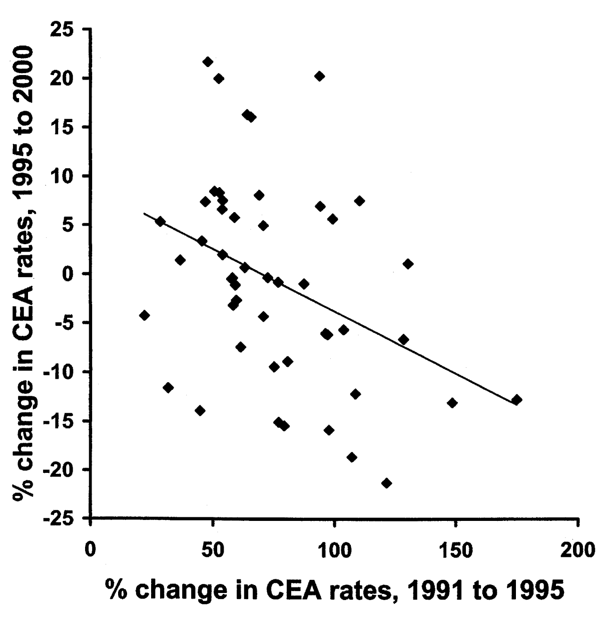

Fig 5. Correlation between state-specific change in carotid-endarterectomy (*CEA*) procedures per 1000 Medicare beneficiaries, 1991 to 1995 and 1995 to 2000 ($r = 0.41$; $P = .0038$).

Canadian study found a much larger geographic variation in CEA rates.[19] In 23 counties of a state, a wide variation in the rates was not explained by the differences in the appropriateness of the use of CEA procedure.[20] The CEA rate in a geographic area is likely to be dependent on the prevalence of carotid stenosis, screening for asymptomatic stenosis, the referral practice for surgery, patient preferences, and access to surgical services in that area. However, the variation in state-specific CEA rates was so large that the differences in the prevalence of carotid stenosis could not fully explain it, if the prevalence was known. Some of this variation is probably due to the differences in screening for asymptomatic but operable carotid stenosis, or to the differences in referral practice. Other reasons for variation in CEA rates may include different interpretation of the clinical guidelines, acceptance of the results of clinical trials of CEA, and overuse or underuse of the procedure.

The results show that the states with relatively low CEA rates in 1991 also had low rates in 1995, even though the percent increase in the rate from 1991 to 1995 was higher in these states than in the states with high baseline CEA rates. These findings suggest that the states with low CEA rates did not have sufficient increase to catch up with the high-rate states by 1995, but that they were prone to

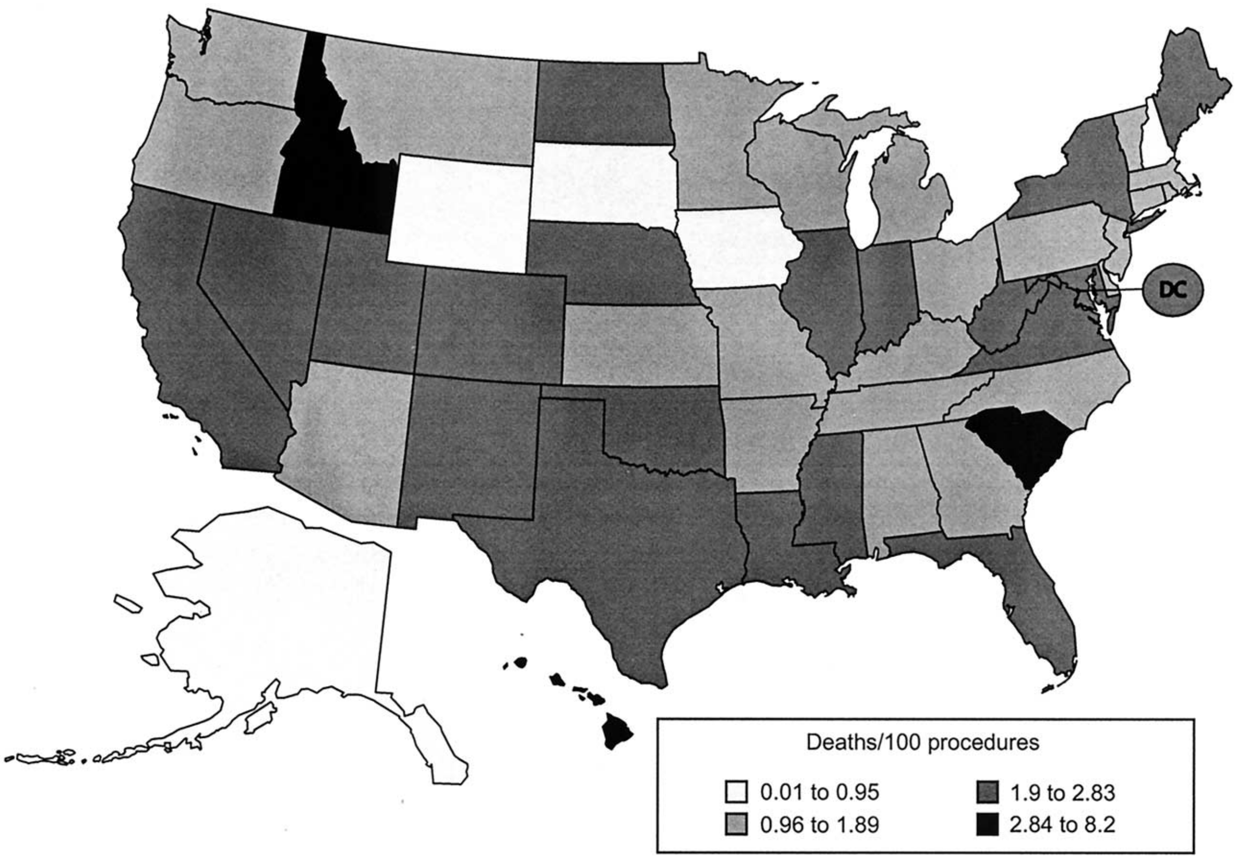

Fig 6. State-specific 30-day postprocedure mortality for Medicare beneficiaries, 1991.

experience a higher increase in the subsequent 5 years. It may be that the states with relatively high CEA rates in 1991 had less room for further increase in the rates from 1991 to 1995, the period of 70% average increase, whereas from 1995 to 2000 CEA rates increased in some states but not in others. This perhaps was the most likely explanation for no correlation between these changes in CEA rates and the baseline (1995) rates.

The states with relatively high 30-day mortality in 1991 had lower percent increase or greater percent decrease in the rate from 1991 to 1995. For example, mortality in 1991 and the decrease in mortality from 1991 to 1995 were highest in the states of Hawaii and Idaho. It may be that a relatively high surgical mortality in a state prompted actions to improve medical care and reduce this adverse outcome. Similarly, the states with high 30-day mortality in 1995 appeared to have lower percent increase or greater percent decrease in the rate from 1995 to 2000. Interestingly, states with a relatively greater decrease in 30-day mortality from 1991 to 1995 had lower decrease in the subsequent 5 years. This finding suggests that there may be a threshold beyond which surgical mortality can not be further reduced. The state-specific CEA rates in each year or increments in these rates over time were not related to any measure of surgical

Fig 7. Correlation between state-specific change in 30-day postoperative deaths per 100 procedures in Medicare beneficiaries, 1991 to 1995 and 1995 to 2000 ($r = -0.35$; $P = .0133$).

mortality, although an increase in CEA rates was expected to be associated with lower surgical mortality. Relatively small variations in state-specific 30-day mortality in 1995 and 2000 may be a reason for this finding.

The highest CEA rates were in the northwest corner of United States, the Midwest, and the "stroke belt" in the South. Although the level of stroke mortality in the general population of a state could be regarded as a crude measure of the need for CEA, it was correlated with the CEA rate in the state. However, there was a relatively lower increase in CEA rates from 1991 to 1995 in the states with high stroke mortality in 1991. This finding suggests that either the stroke mortality in the general population was not a valid measure of the need for CEA in some states, or the need was unmet in these states. Future studies using clinical data on individual patients may explain these correlations.

The proportion of beneficiaries enrolled in the managed care sector of Medicare in 1991, 1995, and 2000 were 5.8%, 10.0%, and 17.3%, respectively. Since there are no data to suggest differences between the two sectors in use of CEA, and since almost all US citizens aged 65 years and older were enrolled in Medicare, the results of this study can be generalized to the US population aged 65 years and older. The measures of variation and correlation between states are likely to have been distorted by the extreme values of CEA procedures and deaths in a year. For example, the wide standard deviation for the mean of 30-day mortality rate in 1991 was due to the fact that mortality exceeded 3.8% in only one state (8.2% in Hawaii) and was less than 0.9 % in only one state (no deaths in Wyoming). These distortions were a function of small numbers of CEA procedures per year in a few states.

This study suggests that the interstate variation in CEA rates has not changed since 1995 but that variation in 30-day mortality has decreased, and that there has been a progressive decline in mortality in all states combined during 1991 through 2000. The overall 30-day mortality was reduced by more than 50% during this period. Some of these measures in different time periods were interrelated. Further research is needed to better explain variations between states. In the absence of disease registries, clinical data could be used to estimate the state-specific prevalence of carotid stenosis. This measure could then be used as the denominator of state-specific "true" rates of CEA. The precision of these rates could be improved by using data on the symptoms and extent of carotid stenosis and the criteria for selecting patients for CEA. Measures to reduce variation may promote appropriate use of CEA procedure and improve the quality of care.

REFERENCES

1. Biller J, Feinberg WM, Castaldo JE, Whittemore AD, Harbaugh RE, Dempsey RJ, et al. Guidelines for carotid endarterectomy: a statement for healthcare professionals from a special writing group of the Stroke Council, American Heart Association. Circulation 1998;97:501-9.
2. Warlow C. Carotid endarterectomy: does it work? Stroke 1984;15: 1068-76.
3. Barnett HJM, Plum F, Walton JN. Carotid endarterectomy—an expression of concern. Stroke 1984;15:941-3.
4. Winslow CM, Solomon DH, Chassin MR, Kosecoff J, Merrick NJ, Brook RH. The appropriateness of carotid endarterectomy. N Engl J Med 1988;318:721-7.
5. Barnett HJM, Eliasziw M, Meldrum HE, Taylor DW. Do the facts and figures warrant a 10-fold increase in the performance of carotid endarterectomy on asymptomatic patients? Neurol 1996;46:603-8.
6. North American Symptomatic Carotid Endarterectomy Trial Collaborators. Beneficial effect of carotid endarterectomy in symptomatic patients with high-grade carotid stenosis. N Engl J Med 1991;325: 445-53.
7. Executive Committee for the Asymptomatic Carotid Atherosclerosis Study. Endarterectomy for asymptomatic carotid artery stenosis. JAMA 1995;273:1421-8.
8. Hsia DC, Krushat WM, Moscoe LM. Epidemiology of carotid endarterectomies among Medicare beneficiaries. J Vasc Surg 1992;16:201-8.
9. Gillum RF. Epidemiology of carotid endarterectomy and cerebral arteriography in the United States. Stroke 1995;26:1724-8.
10. Patrick SJ, Concato J, Viscoli C, Chyatte D, Brass LM. Sex differences in the management of patients hospitalized with ischemic cerebrovascular disease. Stroke 1995;26:577-80.
11. Wennberg DE, Lucas FL, Birkmeyer JD, Bredenberg CE, Fisher ES. Variation in carotid endarterectomy mortality in the Medicare population: trial hospitals, volume, and patient characteristics. JAMA 1998; 279:1278-81.
12. Hsia DC, Moscoe LM, Krushat WM. Epidemiology of carotid endarterectomy among Medicare beneficiaries: 1985-1996 update. Stroke 1998;29:346-50.
13. Morasch MD, Parker MA, Feinglass J, Manheim LM, Pearce WH. Carotid endarterectomy: characterization of recent increases in procedure rates. J Vasc Surg 2000;31:901-9.
14. Ramani S, Byrne-Logan S, Freund KM, Ash A, Yu W, Moskowitz MA. Gender differences in the treatment of cerebrovascular disease. J Am Geriat Soc 2000;48:741-5.
15. Gross CP, Steiner CA, Bass EB, Powe NR. Relation between prepublication release of clinical trial results and the practice of carotid endarterectomy. JAMA 2000;284:2886-93.
16. Sheikh K, Bullock C. Sex differences in carotid endarterectomy utilization and 30-day post-operative mortality. Neurology 2003;60:471-6.
17. Rothman K. Standardization of rates. In: Modern Epidemiology. Boston: Little Brown & Co;1986. p. 41-9.
18. Oldham PD. A note on the analysis of repeated measurements of the same subjects. J Chron Dis 1962;15:969.
19. Feasby TE, Quan H, Ghali WA. Geographic variation in the rate of carotid endarterectomy in Canada. Stroke 2001;32:2417-22.
20. Leape LL, Park RE, Solomon DH, Chassin MR, Kosecoff J, Brook RH. Does inappropriate use explain small-area variations in the use of health care services? JAMA 1990;263:669-72.

Submitted Feb 12, 2003; accepted Mar 20, 2003.

Additional material for this article may be found online at www.mosby.com/jvs.